

CFD Workbench

FreeCAD-CFD Workbench

Tutorial 4: External aerodynamics of a UAV

CFD Workbench

WORKBENCH

This workbench aims to help users set up and run CFD analysis. It guides the user in selecting the relevant physics, specifying the material properties, generating a mesh, assigning boundary conditions and setting the solver settings before running the simulation. Where possible best practices are included to improve the stability of the solvers.

INSTALLATION

WINDOWS:

- <https://www.freecadweb.org/wiki/Download>
- Install CfdOF from Tools | Addon manager
- Go to Edit | Preferences | CFD to check and install dependencies

LINUX:

- https://www.freecadweb.org/wiki/Install_on_Unix
- Install CfdOF from Tools | Addon manager
- Install OpenFOAM (5.0 recommended) (<https://openfoam.org/download/>)
- Install Paraview (tested with 5.0.1)
- Optional - Install GMSH (optional, 2.13+)
- Go to Edit | Preferences | CFD to check dependencies and install cfMesh

LATEST INFORMATION

Please see the CfdOF [README file](#) for up-to-date information.

LEAD DEVELOPERS

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UAV aerodynamics

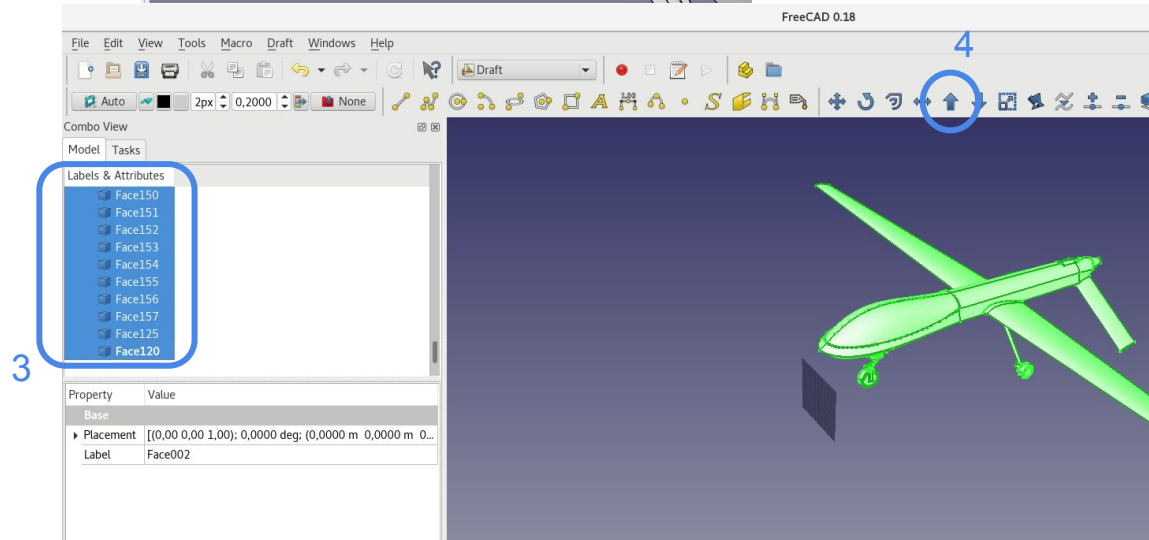
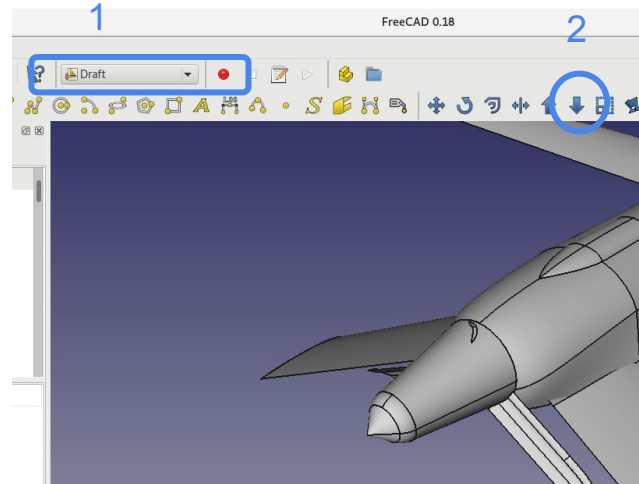
- To demonstrate how to model viscous flow over an unmanned aerial vehicle.
- Study the effect of including the camera gimbal



Part Design

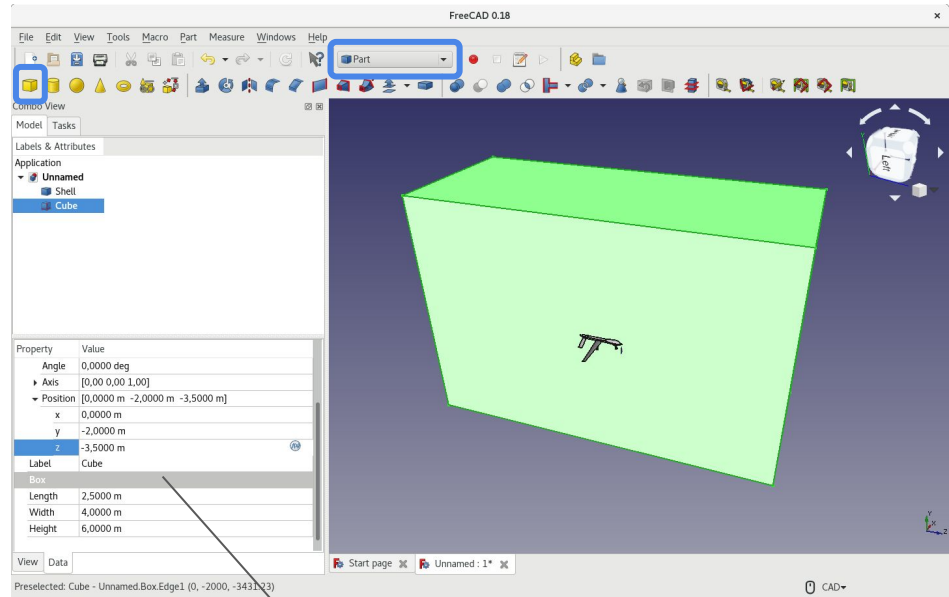
Geometry

- Open the supplied .igs file in FreeCAD
- We wish to remove the propeller blades for the analysis.
- Open the 'Draft' workbench, select the 'UAV' object in the tree view, and click the 'Explode' button.
- Select and delete each face of the propeller.
- Select all faces and click the 'join' button to re-combine them.



External flow domain

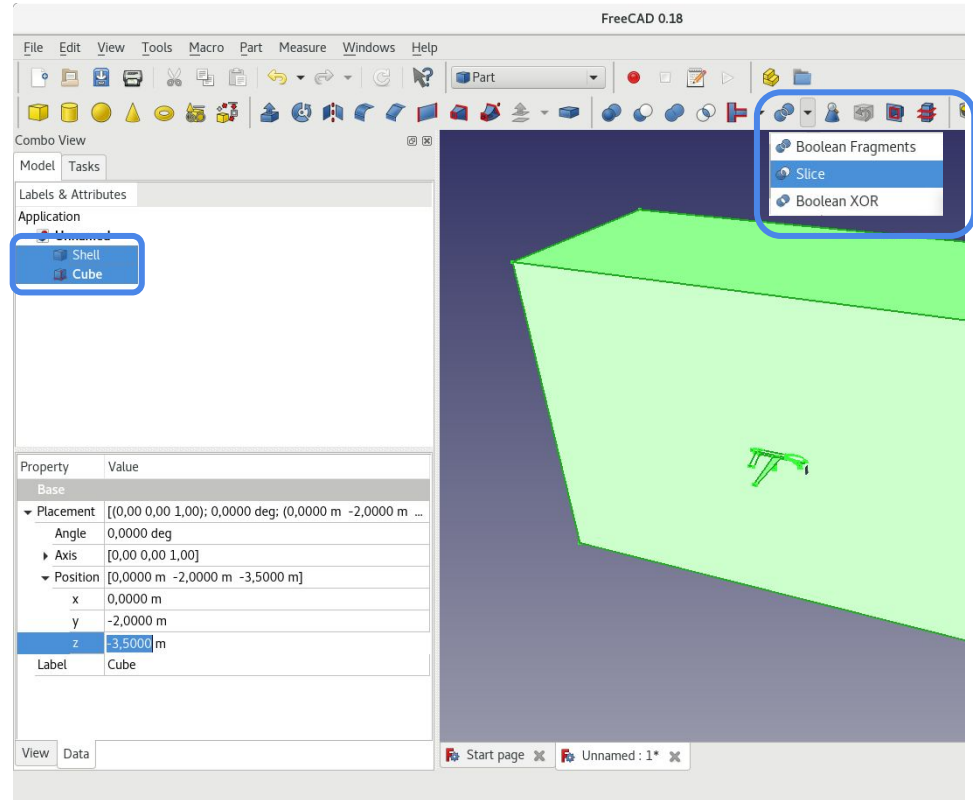
- Open the 'Part' workbench and create a cube to hold the external mesh.
- Set the position and dimensions as shown.
- For the final analysis, the far field domains should be much further from the body
 - Rule of thumb is 10 times its characteristic length
 - We choose closer boundaries for a quicker preliminary analysis
- We are cutting the body in half in order to save time by simulating only half of the symmetric domain



Axis	[0,00 0,00 1,00]
Position	[0,0000 m -2,0000 m -3,5000 m]
x	0,0000 m
y	-2,0000 m
z	-3,5000 m
Label	Cube
Box	
Length	2,5000 m
Width	4,0000 m
Height	6,0000 m

External flow domain

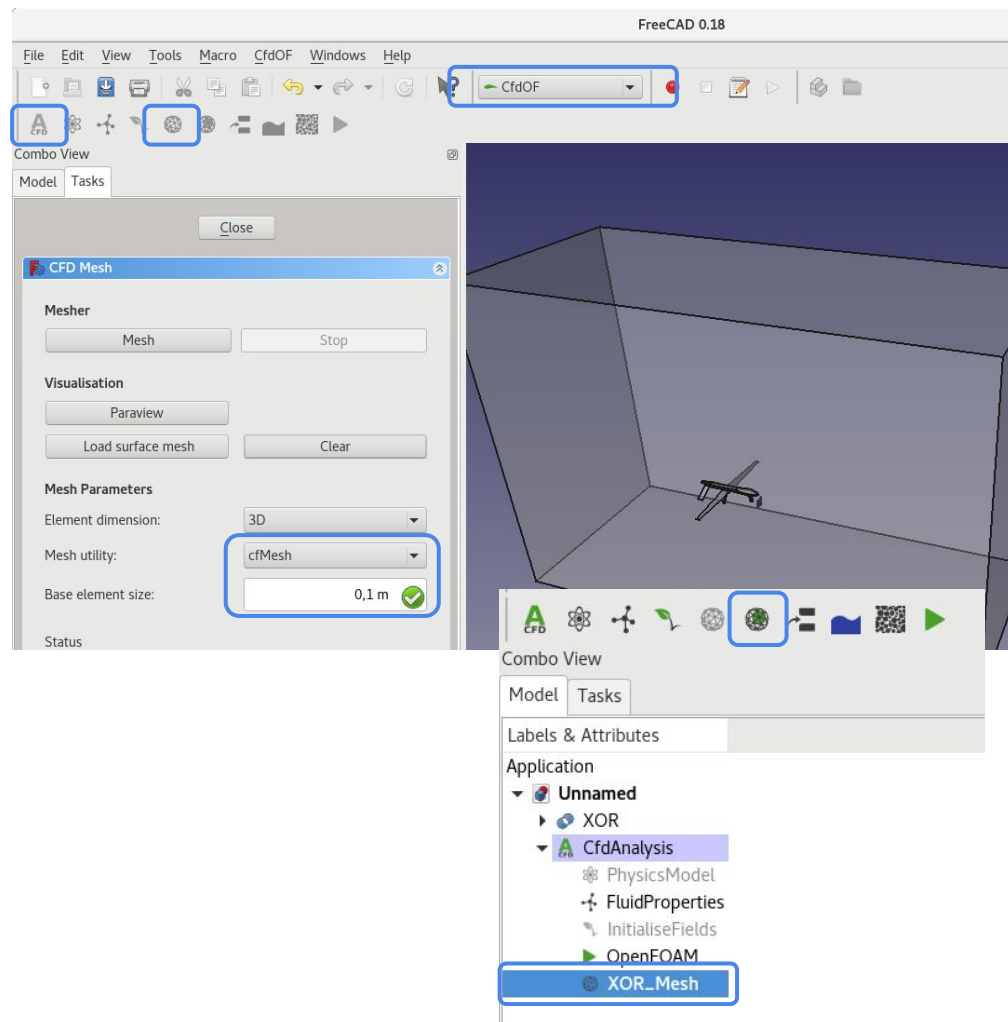
- To cut out the aircraft from the outer domain, **first** select the 'Cube' object, then the 'Shell' object (holding Ctrl), and choose the 'Slice' operation in the Part workbench
 - The 'Slice' operation cuts away from the first selection using the second (and any further) selections
 - The 'Cut' operation is an alternative, but only works for watertight solid objects (often not the case for imported CAD).



Mesh generation and mesh refinement with cfMesh

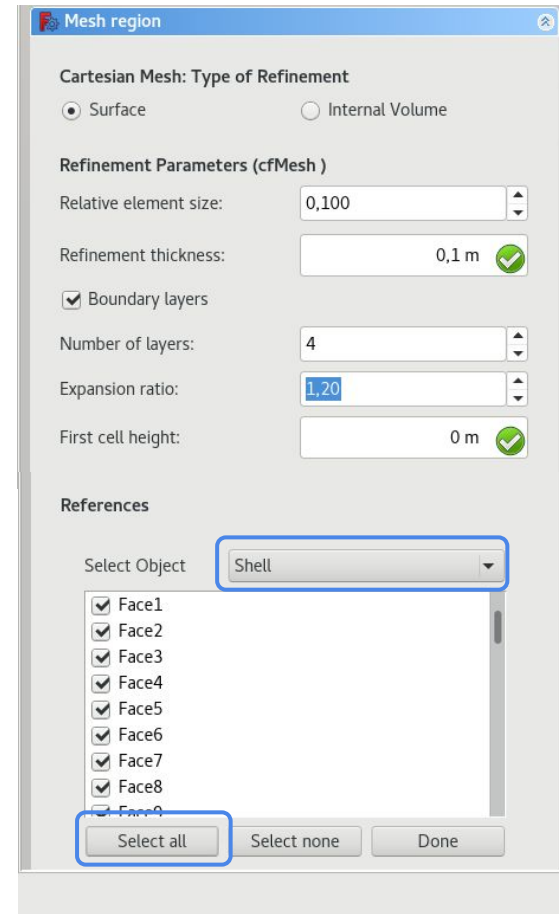
Create Mesh object and refinement region

- Activate the CfdOF Workbench
- Create an 'Analysis' object
- Select the 'Slice' object and click the 'Mesh' button.
- Select the cfMesh mesher and a base element size of 0.1 m
- Select the mesh object and click the 'Mesh region' button



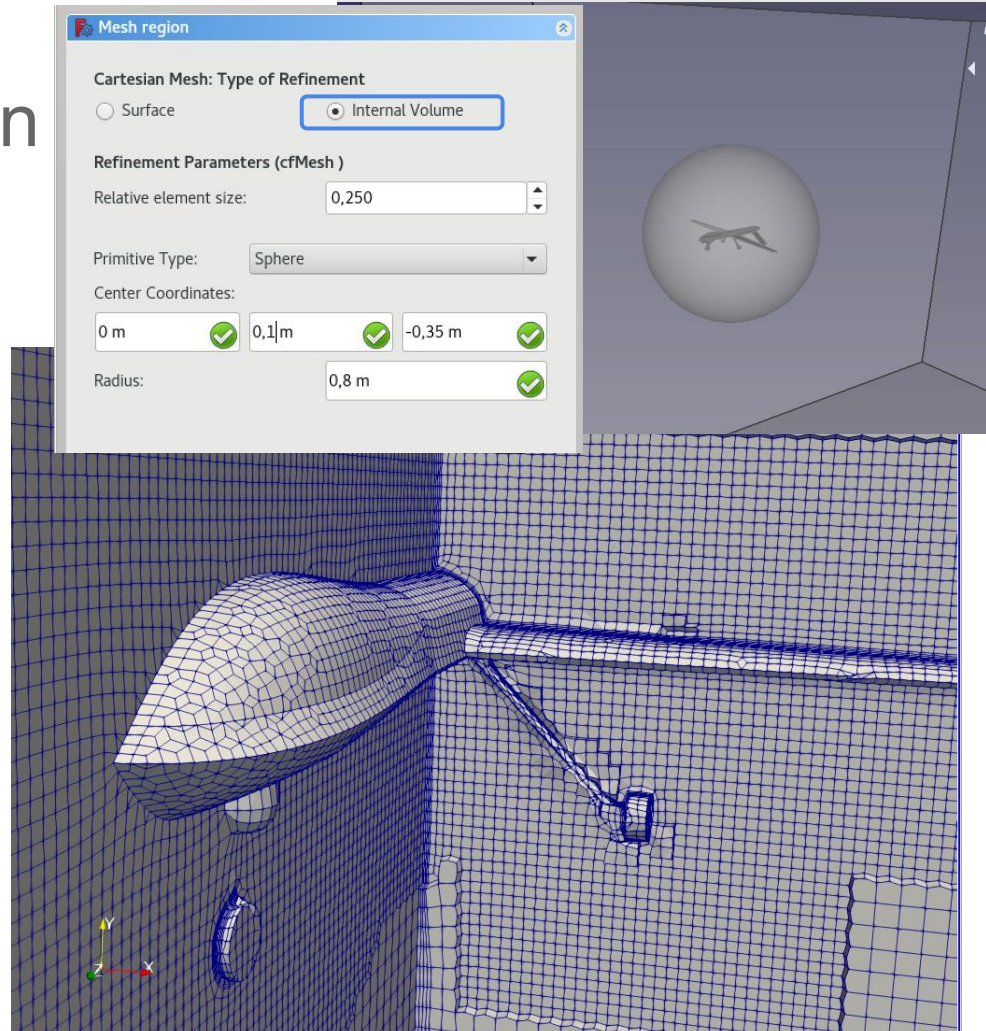
Surface refinement region

- For 1/10th refinement within 0.1 m of the body, input a refinement thickness of 0.1m and a relative element size of 0.1.
- Here we choose 4 boundary layers with an expansion ratio of 1.2.
 - See Tutorial 3 for more information on boundary layers
 - For non-smooth geometries, the mesher and/or solver may struggle if too many boundary layers are added.
- To easily select the entire body of the aircraft, click 'Select from list', then choose the 'Shell' object and click 'Select all'



Volume refinement region

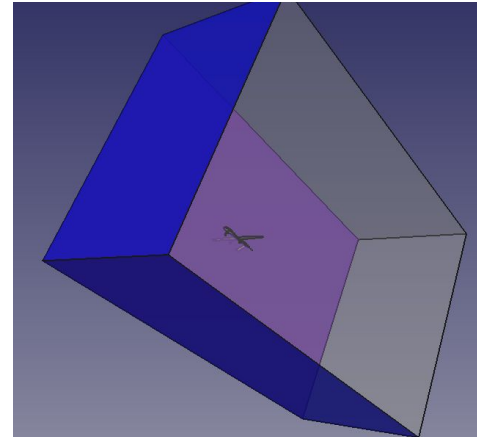
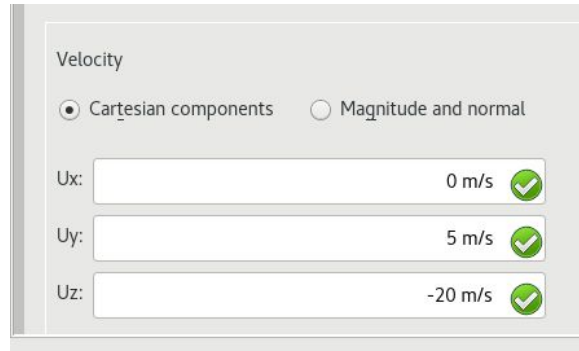
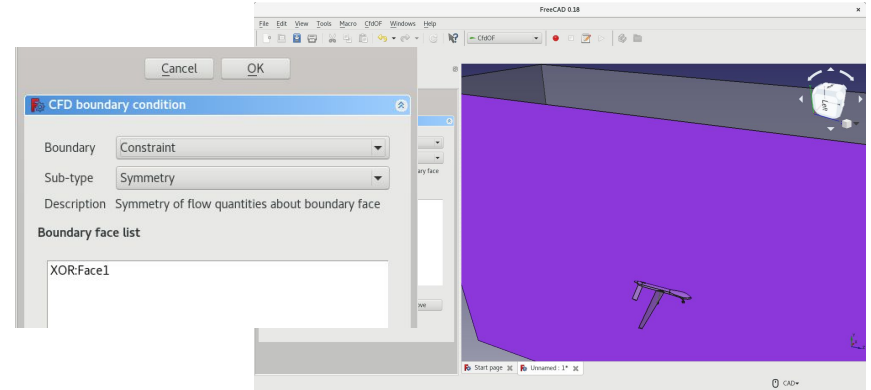
- To achieve a more gradual refinement from the far field to the surface of the body, we introduce an additional volume refinement
- Select the 'Slice_mesh' object and click the 'Mesh region' button as before
- Select 'Internal volume' and enter the parameters as shown
 - cfMesh currently only supports spherical and rectangular refinement zones
- Return to the mesh object and click 'Mesh'.
- Click 'Paraview' to view the result.



CFD analysis

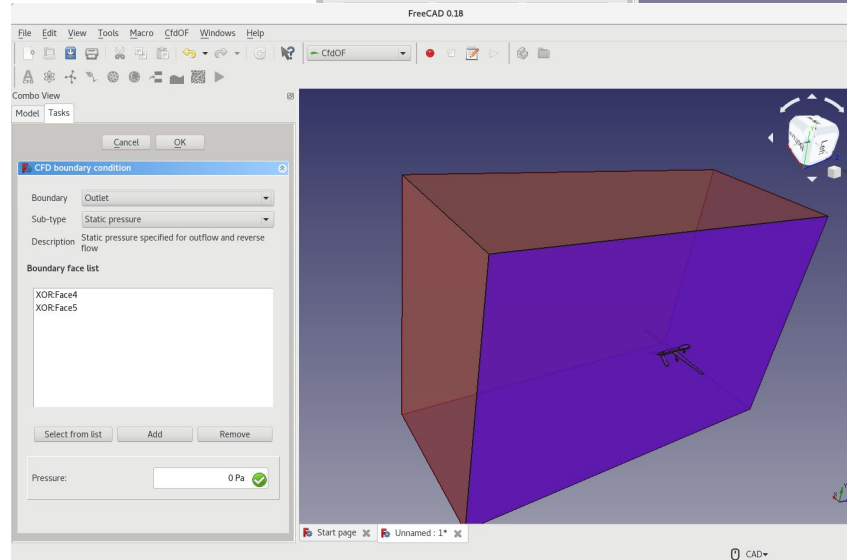
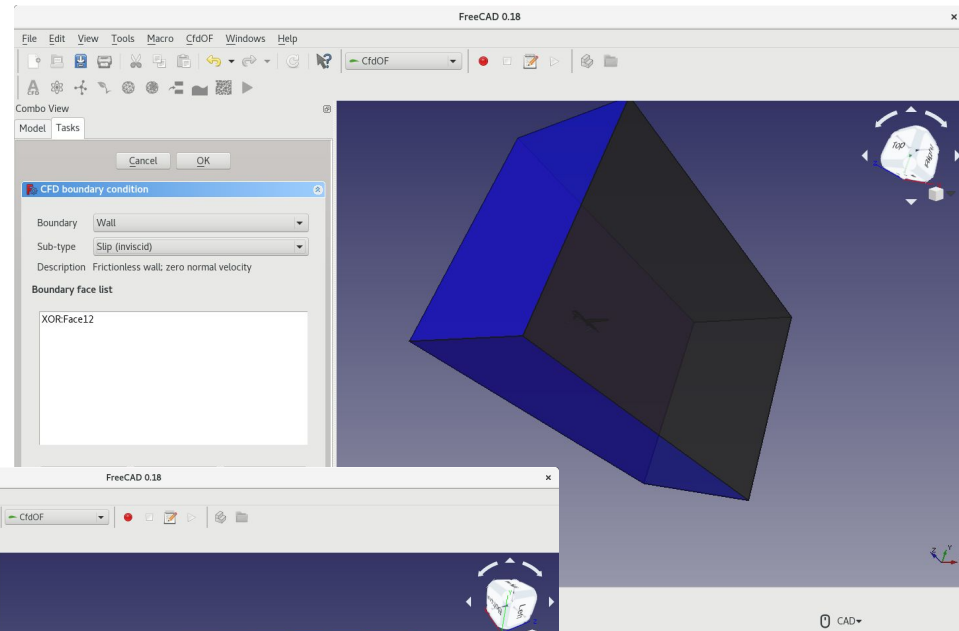
Add boundary conditions

- Create a CFD boundary condition of 'Constraint' type 'Symmetry' for the central cutting face
- Create a 'Uniform velocity' inflow boundary condition with the parameters shown below and add the lower and front faces.
 - Flight at 74 km/h and 14° angle of attack



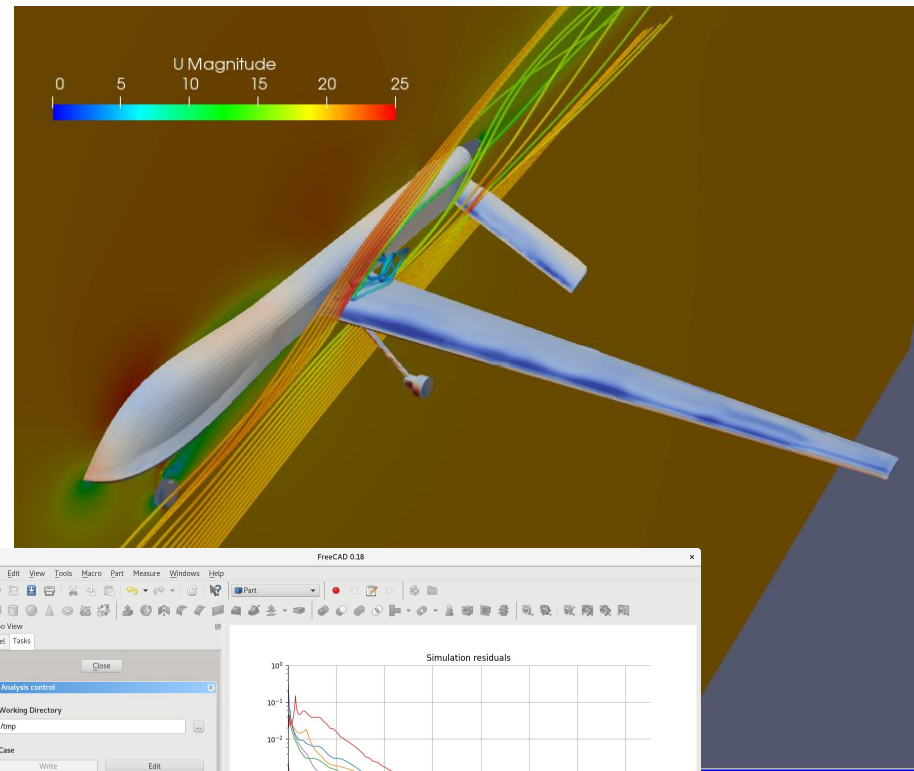
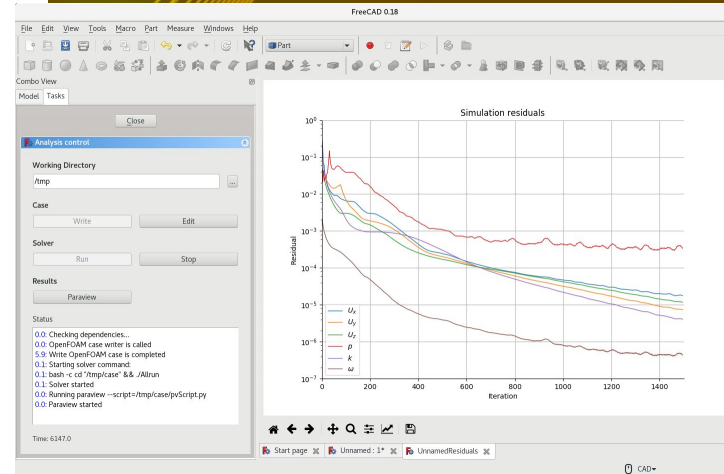
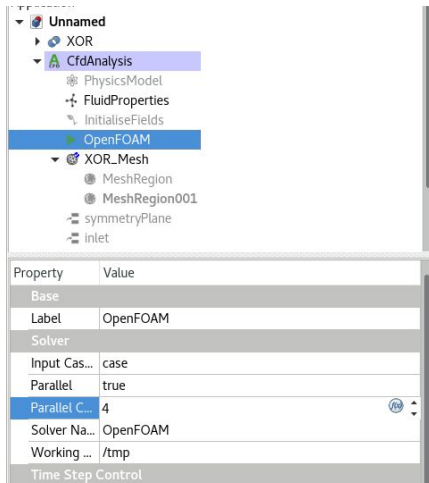
Add boundary conditions

- Create a slip wall boundary condition for the outer face
- Create a 'Static pressure' outflow boundary and add the upper and back faces.
- The remaining settings include:
 - Fluid: air
 - Initialise with potential flow



Run analysis

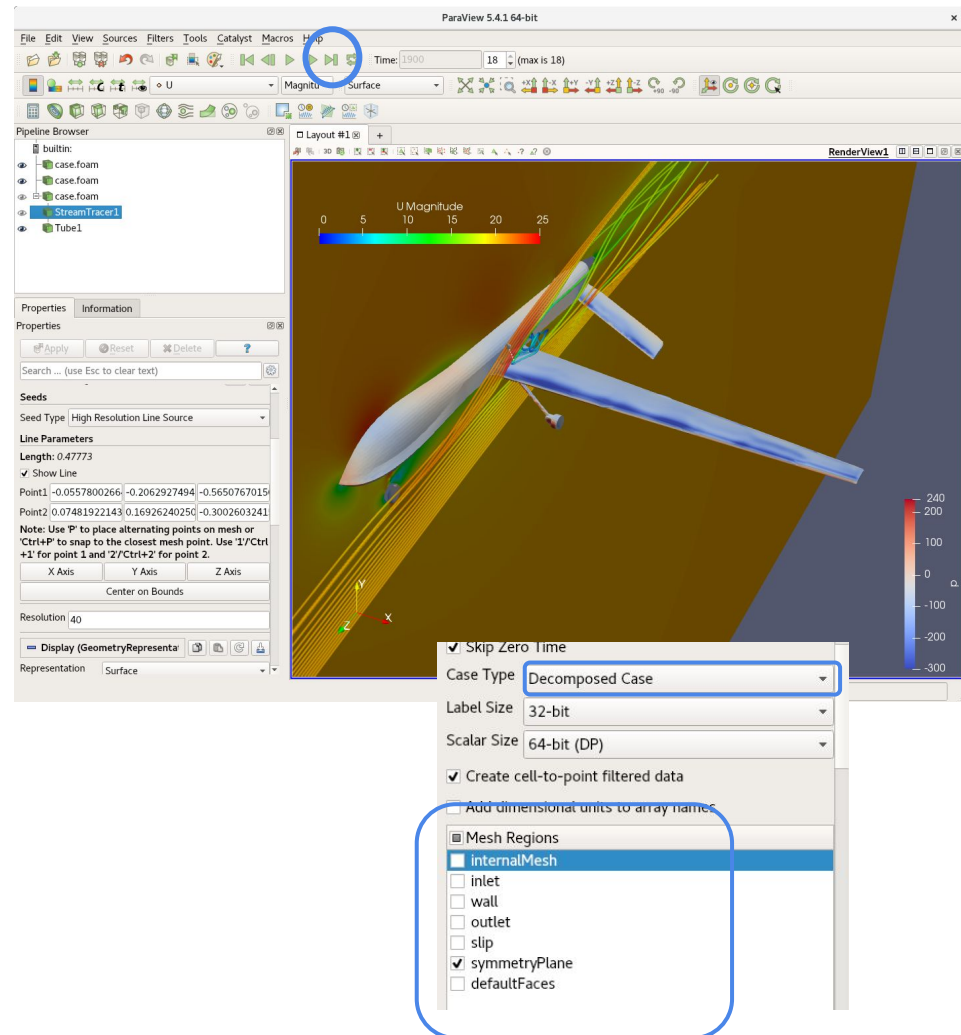
- For the 'OpenFOAM' solver object, set parallel processing to true and the desired number of parallel cores
- Double click on the 'OpenFOAM' object and click Write, then Run.



Post-processing

Visualisation

- Click 'Paraview', go to last time step
- Re-load 'pv.foam', select different patches to visualise if desired
- Add stream trace to object with internalMesh selected
- **Warning:** For incompressible, single phase solvers, OpenFOAM writes 'Kinematic pressure' = p/ρ



Integrated forces output

- While the analysis is running, click 'Edit' to open the case directory and edit the system/controlDict file.
- Paste the contents of the supplied 'forces' file at the end.
- Integrated forces and moments (about 'CofR') are written to the file:

postProcessing/forces_all/0/forces.dat

- Use to determine lift, drag, etc
- Re-run analysis with and without camera gimbal, gear retracted, etc, and find effect on forces

```
runTimeModifiable true;

libs
(
    // Needed for availability of porous baffle boundary in
    potentialFoam
    "libturbulenceModels.so"
);

functions
{
    forces_all
    {
        type            forces;
        libs             ( "libforces.so" );
        patches
        (
            wall
        );
        rho              rhoInf;
        rhoInf           1.2;
        log              off;
        writeControl      timeStep;
        writeInterval     1;
        CofR              ( 0 0 0 );
    }
}

// *****
//
```

The End